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Optimization of production process scheduling at Mataram Convection using the Campbell-Dudek and Smith method and the Ho and Chang method

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Abstract

Konveksi Mataram (Djagoan Kaos dan Seragam) is one of the industries engaged in the manufacture of various types of clothing models with fabric as the basic material. So far, the scheduling method used by the company is the First Come First Serve method, in which the completion of production is based on order-to-order data. In this case, with high order intensity, companies often experience difficulties in completing orders according to a predetermined pick-up time. The problems experienced by the company were caused by the production process scheduling that was not optimal. Based on the problems encountered, the purpose of this research is to obtain the optimal scheduling sequence by determining the smallest makespan (minimum total completion time) of the application of the method to the production process. The methods used in this study are the Campbell-Dudek and Smith method and the Ho and Chang method and from these two methods, it is known that the smallest production process is optimal. Based on the results of calculations using the Campbell-Dudek and Smith method, the optimal scheduling sequence with the smallest makespan is 39163 minutes or the production process will be completed in 73 working days. While the results of calculations using the Ho and Chang method obtained the optimal scheduling sequence with the smallest makespan of 38660.50 minutes or the production process will be completed in 72 working days. From the makespans of the two methods, the Ho and Chang method is superior to the Campbell-Dudek and Smith method with a difference of 502.50 minutes or about 1 working day, whereas when compared to the company's initial method, namely First Serve First Come with a makespan of 43025.50 minutes, the HC method can make completion time efficient with a difference of 4365 minutes or about 8 working days.

Keywords: Campbell-Dudek and Smith methods, first come first serve, Ho and Chang, makespan, production scheduling

MSC2020: 90B30

1. Introduction

In [1] the manufacturing industry is the process of converting raw materials into products, in which manufacturing adds value to the material by changing its shape or by combining it with other similarly modified materials. One example of a manufacturing industry is the textile and garment industry, this industry is engaged in manufacturing services of various types of clothing/uniform models with fabric as a base material [2].

In some companies, errors in preparing production schedules can not only disrupt efforts to control production machines but also affect the company's production volume [3]. The production process generally has a situation where quality is directly affected by the degradation of the production system itself [4]. Every company strives to have the most effective and efficient scheduling so that it can increase the resulting productivity with the minimum total cost and time [5]. In a production activity, to obtain an optimum result, all production activities must first be planned properly [6].

Konveksi Mataram (Djagoan Kaos dan Seragam) is one of the industries engaged in the textile and garment sector. Mataram Convection (Djagoan T-shirts and Uniforms) produces various types of products such as uniforms, PDH (daily official clothes), jackets, t-shirts, and others. At certain times, orders usually experience a significant increase, but based on the initial method used, namely FCFS (First Come First Serve), where the completion of production is carried out in order of arrival of orders, the first incoming order will be completed first and so on until the last order. This is certainly not efficient because it causes a lot of work waiting to be done while the existing resources are still doing other tasks. One of the impacts is that orders cannot be completed by a predetermined deadline, if this continues to happen, the profits that the company will get will not be maximized. Improper production scheduling will also increase production costs, increase machine idle time, and result in delays in work in the production process because the deadline for completing work is exceeded [7].

Based on the problems encountered, Konveksi Mataram needs to evaluate by rescheduling the order of the production process to streamline the total time of the production process being carried out. The heuristic method that will be used to solve production scheduling problems this time is to use the CDS (Campbell-Dudek and Smith) method and the HC (Ho and Chang) method. By doing production scheduling, it is hoped that the company can control production activities so that production failures do not occur [8], besides that the company's resources can be utilized optimally [9].

2. Methodology

2.1. CDS Method

According to [10] The method put forward by Campbell, Dudek, and Smith (CDS) in 1965 is a development of the Johnson Rule, to produce better flowtime and makespan [11]. The Campbell Dudek and Smith (CDS) method is "a method that solves the n job problem on m flow shop machines into $m-1$ sets of two flow shop machine problems by dividing m machines into two groups, then sequencing jobs on both machines used Johnson's algorithm. After obtaining $m-1$ alternative job sequences, the sequence with the smallest makespan is selected [12].

For scheduling n jobs against m machines, the Johnson algorithm is carried out as follows:

a. Take the first schedule ($k=1$). For all existing jobs, find value $t_{i,1}^{*}$ and $t_{i,2}^{*}$ the minimum which is the processing time on the first and second machines, $t_{i,1}^{*} = t_{i,1}$ and $t_{i,2}^{*} = t_{i,2}$.

b. If the minimum time is obtained on the first machine, (eg $t_{i,1}$), then place the task at the beginning of the scheduling series and if the minimum time is obtained on the second machine (eg $t_{i,2}$), the task is placed at the end position of the scheduling series.

c. Remove the tasks from the list and arrange them in the form of a scheduling series. If there are still jobs left, go back to step a, otherwise, if there are no more jobs left, it means that the schedule has been completed. Thus the processing time of the two machines, namely the first machine ($t_{i,1}^{*}$) and the second machine ($t_{i,2}^{*}$) on the K schedule is:

$$t_{i,1}^{*} = \sum_{k=1}^{k} t_{i,k} \quad (1)$$

$$t_{i,2}^{*} = \sum_{k=1}^{k} t_{i,m-k+1} \quad (2)$$

the schedule to $K=(m-1)$ has been reached, meaning that the job scheduling has been completed. To determine the value of the makespan can be calculated using the following formula:

$$t_{1,1}^{*} = t_{1,1}$$
$$t_{1,2}^{*} = t_{1,1}^{*} + t_{1,2}$$
$$\vdots$$
$$t_{1,j}^{*} = t_{1,1}^{*} + t_{1,2}^{*} + \cdots + t_{1,j-1}^{*} + t_{1,j}$$

$$t_{2,1}^{*} = t_{1,1}^{*} + t_{2,1}$$

$$t_{2,2}^{*} = \text{maks}\{t_{1,2}^{*}, t_{2,1}^{*}\} + t_{2,2}$$
$$\vdots$$
$$t_{i,j}^{*} = \text{maks}\{t_{(i-1),j}^{*}, t_{(i),j-1}^{*}\} + t_{i,j}$$

2.1.1. CDS Mathematical Model

In [13] mathematically the assignment problem can be expressed in the form of the Xij variable, namely:

$$X_{ij} = \begin{cases} 1, \text{if the object i is assigned to task j,} \\ 0, \text{if the object i is not assigned to task j.} \end{cases}$$

We can construct an objective function that minimizes the total production time:

$$\text{Minimize } F = \sum_{i=1}^{m}\sum_{j=1}^{n} t_{ij}\, x_{ij}$$

with the following constraint function:

$$\sum_{i=1}^{m} x_{ij} = 1 \text{ for } j = 1, 2, ..., n.$$

This means that only one job is done by the machine to i, i = 1, 2, .., n.

$$\sum_{j=1}^{n} x_{ij} = 1 \text{ for } i = 1, 2, ..., m.$$

This means that only one machine should be assigned to the job to j, j=1, 2, ..., n.

$$x_{ij} \geq 0 \text{ for all } i \text{ and } j.$$

where i : machine (i = 1, 2, …, m); j : *job* (j = 1, 2, …, n); F : objective function; $X_{i,1}$: declares the decision variable for assigning machine i to job j; $t_{i,j}$: represents the processing time of the *j*th order job on machine i.

2.1.2. Flowchart CDS method

In [14] The following flow chart describes the steps or stages in performing the scheduling process using the CDS method.

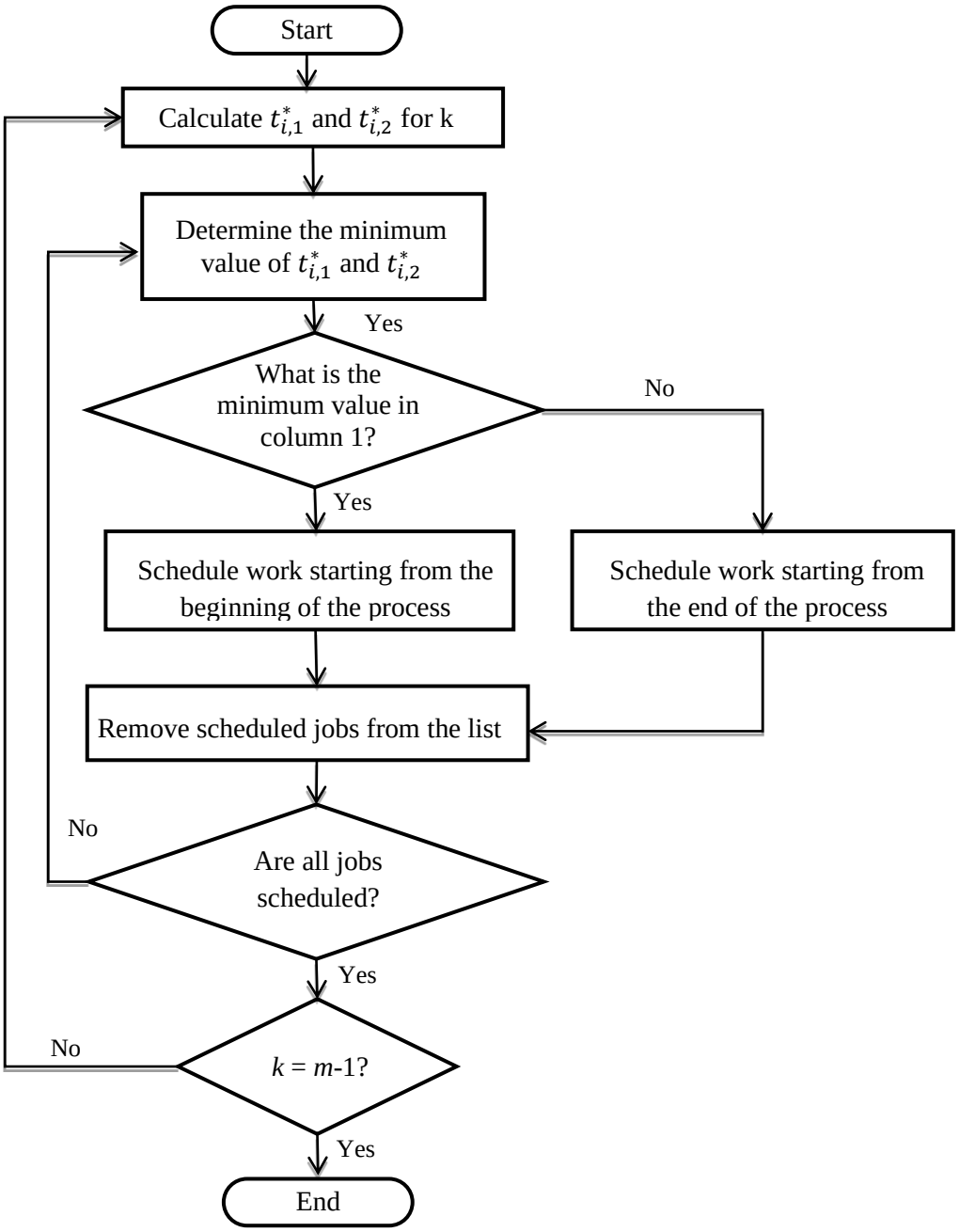


Figure 1. Flowchart CDS method

2.2. HC Method

In [15], Ho and Chang introduced a new heuristic technique to solve flow-shop scheduling problems and minimize the makespan, Ho and Chang's new heuristic method is based on the principle of minimizing gaps. between successive operations that will result in a higher-quality solution. A gap is defined as the time between the end of job I on machine *j* and the start of job *i* on a machine (*j* + 1).

In [16] the following are the steps for working on the HC algorithm:

1. Generating an initial solution.
2. Calculate the gap value using the following formula:

$$D_{i,j}^{k} = t_{i,k+1} - t_{jk}$$

with $i, j = 1, 2, \ldots, n$; $i \neq j$; n = number of jobs; $k = 1, 2, \ldots, (m-1)$; m = number of machines; t = time; $D_{i,j}^{k}$ = gap value.

If a job is followed by the job on the schedule, then a positive $D_{i,j}^{k}$ value means that job must wait on the machine $(k + 1)$ for at least $D_{i,j}^{k}$ until the job is finished. While a negative $D_{i,j}^{k}$ value means that there is the idle time between job and job on the machine $(k + 1)$.

3. Determine the value of the k factor (fk), which is a value needed to reduce the negative gap value, using the following formula:

$$\text{Factor } k\ (fk) = \left\{\left(\frac{(1-0.1)}{(m-2)}\right) \times (\ m\ -\ k\ -\ 1)\right\}\ +\ (0.1).$$

4. Determine the δ_{ij}^{k} value. If the value of $D_{i,j}^{k} < 0$, then the value of δ_{ij}^{k} is equal to the value of, whereas if the value of $D_{i,j}^{k}$ is other than that, then the value of $\delta_{ij}^{k} = 1$.
5. Calculate the value of the overall revised gap using the equation:

$$d_{ij} = \sum_{k=1}^{m-1} D_{ij}^{k} \delta_{ij}^{k}$$

with δ_{ij}^{k} = gap value discount function; $D_{i,j}^{k}$ = gap value; d_{ij} = the value of the overall revised gaps.

6. Determine the P_l value, set the value of $a = 1$ and the value of $b = n$ (number of jobs).
7. Find the largest value called X from $d_{p_a p_l}$ where P_a is the job position a in the initial solution and P_l is the job at the position l where $a < l < b$. Then determine the value of u (u is the value associated with X).
8. Finding the smallest value called Y from $d_{p_l p_b}$ where P_b is the job position b in the initial solution and P_l is the job at the position l where $a < l < b$. Then determine the value of v (v is the value associated with Y).
9. If $(X < 0)$, $(Y > 0)$ and $(|X|\ |Y|)$, then go to step 12.
10. If $(X < 0)$, $(Y > 0)$ and $(|X| > |Y|)$, then go to step 13.
11. If $(|X| > |Y|)$, then go to step 12. If not, go to step 13.

12. Determine the value of $a = a + 1$, and swap the job at position a with the job at position u. Then proceed to step 14.
13. Determine the value of $b = b - 1$, and swap the job at position b with the job at position v.
14. If the new schedule has a better performance level or is the same as the old schedule, then the schedule will be the initial solution. If not, then the old schedule will still be used as the initial solution.
15. If $b = a + 2$, then STOP. If not, then go back to step 7.

2.2.1. HC Mathematical Model

In [16], mathematically the assignment problem can be expressed in the form of variable δ_{ij}^{k} namely:

$$\delta_{ij}^{k} = \begin{cases} \text{factor } (k), \text{if } D_{i,j}^{k} < 0, \\ 1, \text{otherwise.} \end{cases}$$

An objective function can be constructed that minimizes the overall value gap:

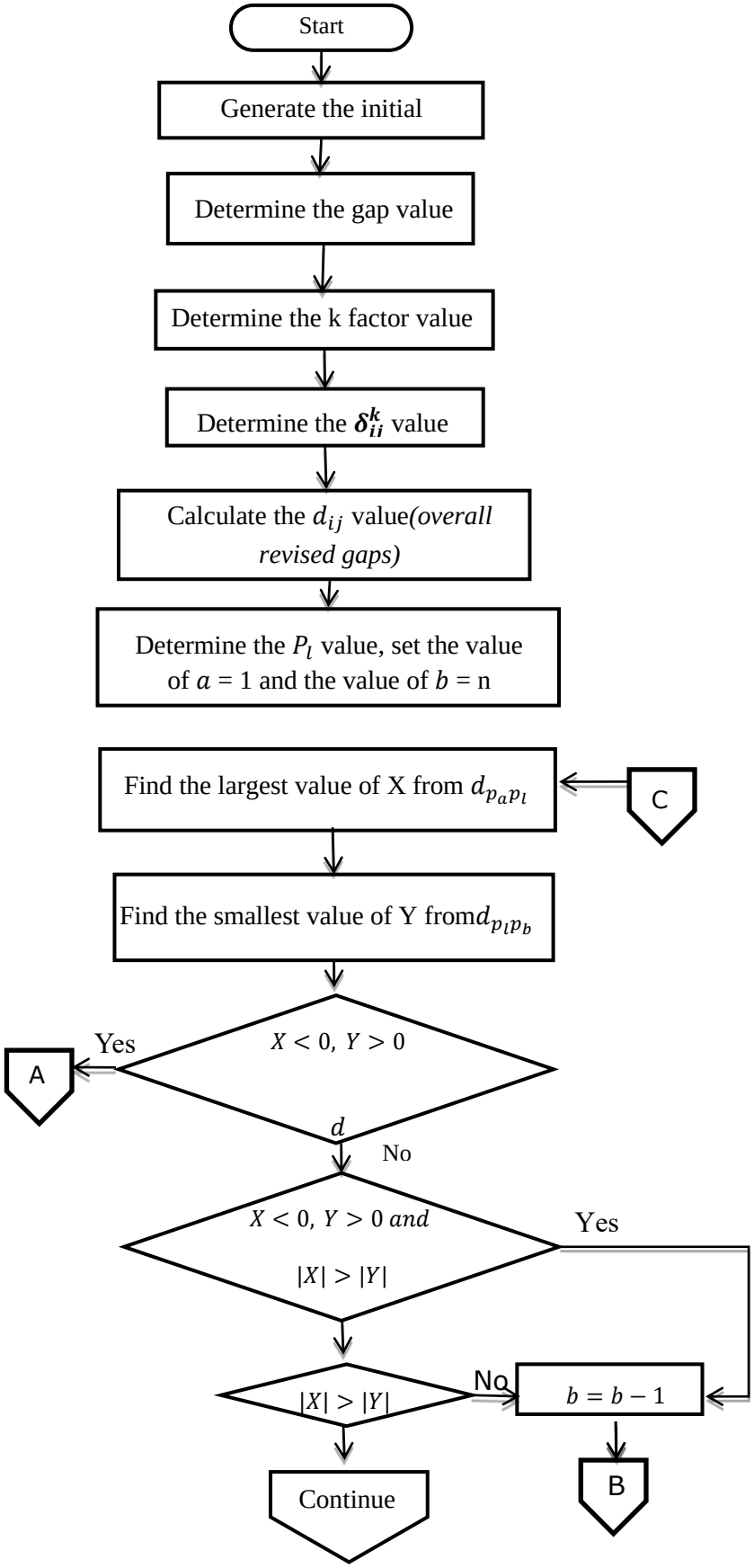
$$\text{minimize } d_{ij} = \sum_{k=1}^{m-1} D_{ij}^{k} \delta_{ij}^{k}$$

with:

$$\sum_{k=1}^{m-1} \delta_{ij} = 1 \text{ for } i, j = 1, 2, \ldots, n; k = 1, 2, \ldots, m-1.$$

2.2.2. *Flow chart HC method*

The following is a flow chart that describes the steps or stages in performing the scheduling process using the HC method.


Start
Generate the initial
Determine the gap value
Determine the k factor value
Determine the δ_{ii}^{k} value
Calculate the d_{ij} value(*overall revised gaps)*
Determine the P_l value, set the value of a = 1 and the value of b = n
Find the largest value of X from $d_{p_a p_l}$
C
Find the smallest value of Y from$d_{p_l p_b}$
$X < 0,\ Y > 0$
Yes
A
d
No
$X < 0,\ Y > 0\ and$
$|X| > |Y|$
Yes
$|X| > |Y|$
No
$b = b - 1$
B
Continue

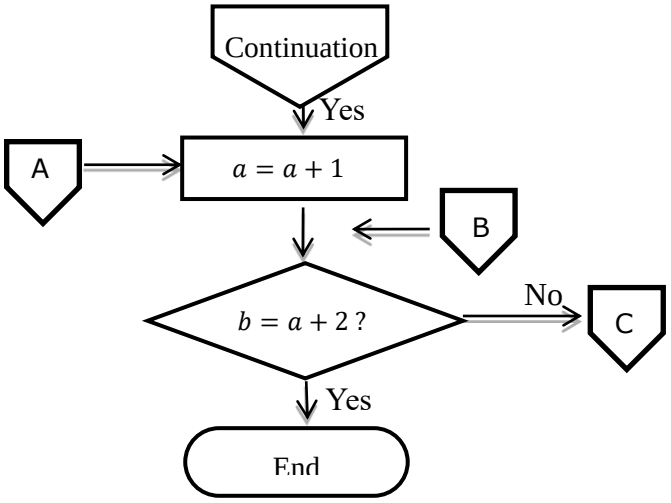


Figure 2. Flowchart HC method

3. Main Results

3.1. Production Data

The following is data on product demand produced in May-June 2022 by Konveksi Mataram with details as presented in Table 1.

Table 1. Order data

Job	**Types of Products**	**Number of Units**
1	Scout uniform	20
2	Sports uniform	465
3	White Uniform	20
4	PDH	527
5	Suit	390
6	alma mater	220
7	Polo Shirt	295
8	Uniform Attribute	1540
9	Belt	510
10	Vest	50
11	Field Shirt	125
12	Jacket	65

Furthermore, from the whole production, there are machines per production process that will complete each stage until the product can be accepted by consumers, the following details are presented in Table 2.

Table 2. Machine data

Machine	Machine Type	Number per Operation (person)
1	Design	1
2	Material Cutting	2
3	Tailoring	6
4	Embroidery/ Screen Printing	2
5	Fastening	1
6	ironing	2
7	Packing	1

Then the last is the data on the range of time needed to complete the product per production process as presented in Table 3.

Table 3. Production process time data

Time Required Range in Minutes							
M / J	Design	Material Cutting	Tailoring	Embroidery / Screen Printing	Penganci-ngan	Setrika	Packing
Scout uniform	30	200	300	83.33	200	150	100
Sports uniform	150	4650	1162.50	1162.50	0	3487.50	2325
White Uniform	30	200	300	83.33	100	150	100
PDH	270	5270	7905	3952.50	2635	2653	2635
Suit	150	2925	650	1462.50	0	975	1950
alma mater	60	4400	4400	916.67	2200	1100	1100
Polo Shirt	180	2212.50	1229.17	2212.50	885	737.50	1475
Uniform Attribute	15	2550	0	0	0	0	2550
Belt	150	2310	0	1283.33	0	0	4620
Vest	30	1137.50	975	487.50	0	325	325
Field Shirt	30	1250	1875	937.50	625	625	625
Jacket	30	500	750	375	0	250	250

3.2. Company Initial Production Scheduling

From the results of interviews conducted, it is known that the company uses the initial method, namely FCFS (First Come First Serve), where the completion of production is carried out based on the order of arrival of the order, the first incoming order will be completed first and so on until the last order. The order of production scheduling for the FCFS method is J_1-J_2-J_3-J_4-J_5-J_6-J_7-J_8-J_9-J_{10}-J_{11}-J_{12}, from the scheduling sequence, calculations are made and the makespan value is 43025.50 minutes. The results of the FCFS method makespan calculation are presented in Table 4.

Table 4. Company initial makespan calculation

	M_1	M_2	M_3	M_4	M_5	M_6	M_7
J_1	30	230	530	613.33	813.33	963.33	1063.33
J_2	180	4880	6042.50	7205	7205	10692.50	13017.50
J_3	210	5080	6342.50	7288.33	7388.33	10842.50	13117.50
J_4	480	10350	18255	22207.50	24842.50	27495.50	30130.50
J_5	630	13275	18905	23670	24842.50	28470.50	32080.50
J_6	690	17675	23305	24586.67	27042.50	29570.50	33180.50
J_7	870	19887.50	24534.17	26799.17	27927.50	30308	34655.50
J_8	885	22437.50	24534.17	26799.17	27927.50	30308	37205.50
J_9	1035	24747.50	24747.50	28082.50	28082.50	30308	41825.50
J_{10}	1065	25885	26860	28570	28570	30633	42150.50
J_{11}	1095	27135	29010	29947.50	30572.50	31258	42775.50
J_{12}	1125	27635	29760	30322.50	30572.50	31508	43025.50

Table 5. Initial makespan

Method	Job Order Scheduling	Makespan (Minutes)
FCFS	J_1-J_2-J_3-J_4-J_5-J_6-J_7-J_8-J_9-J_{10}-J_{11}-J_{12}	43025.50

3.3. Production Scheduling Using the CDS Method

The data that has been obtained will be processed using this method, the data consists of 12 jobs that will go through 7 machines in sequence to produce a product. The order of the scheduling process that may be generated by the CDS method is as many as k iterations (alternative job sequences), aiming to produce the minimum total completion time possible. The number of iterations $k = m - 1$ then $k = 7 - 1 = 6$ iterations.

The iteration starts by calculating the processing time of $t_{i,1}^*$ and $t_{i,2}^*$with equations (1) and (2) in each iteration (k) starting from iterations $1,2, \dots, m-1$, then the job sequence can be obtained by selecting minimum $t_{i,1}^*$ and $t_{i,2}^*$values if the minimum time is obtained on $t_{i,1}^*$place the task at the beginning of the scheduling series and if the minimum time is obtained on $t_{i,2}^*$ the task is placed at the end position of the scheduling series, do it until all jobs are scheduled. The following is the order of each job from the iteration results which is then calculated as the makespan value. The results obtained are presented in Table 6.

Table 6. Comparison of makespan of CDS method for each iteration

Iteration	Job Order Scheduling	Makespan (Minutes)
k = 1	J_8-J_1-J_3-J_{10}-J_{11}-J_{12}-J_6-J_2-J_5-J_9-J_7-J_4	47400.50
k = 2	J_1-J_3-J_9-J_2-J_4-J_5-J_8-J_7-J_6-J_{11}-J_{10}-J_{12}	40715.50
k = 3	J_9-J_4-J_2-J_6-J_7-J_5-J_8-J_{11}-J_{10}-J_{12}-J_1-J_3	39163
k = 4	J_9-J_4-J_2-J_6-J_7-J_5-J_{11}-J_8-J_{10}-J_{12}-J_1-J_3	39163
k = 5	J_1-J_3-J_9-J_2-J_4-J_6-J_7-J_5-J_{11}-J_8-J_{10}-J_{12}	40715.50
k = 6	J_3-J_1-J_{12}-J_8-J_{10}-J_9-J_{11}-J_5-J_7-J_2-J_6-J_4	47415.50

Based on the table above, it can be seen that the results of the calculation using the CDS method obtained the job order with the smallest makespan of 39163 minutes for k = 3 and

k = 4 with the job order being J_9-J_4-J_2-J_6-J_7-J_5-J_8-J_{11}-J_{10}-J_{12}-J_1-J_3 and J_9-J_4-J_2-J_6-J_7-J_5-J_{11}-J_8-J_{10}-J_{12}-J_1-J_3. The results of calculating the makespan of the CDS method for k = 3 are presented in Table 7.

Table 7. Makespan calculation of CDS method for K = 3

	M_1	M_2	M_3	M_4	M_5	M_6	M_7
J_9	150	2460	2460	3743.33	3743.33	3743.33	8363.33
J_4	420	7730	15635	19587.50	22222.50	24875.50	27510.50
J_2	570	12380	16797.50	20750	22222.50	28363	30688
J_6	630	16780	21197.50	22114.17	24422.50	29463	31788
J_7	810	18992.50	22426.67	24639.17	25524.17	30200.50	33263
J_5	960	21917.50	23076.67	26101.67	26101.67	31175.50	35213
J_8	975	24467.50	24467.50	26101.67	26101.67	31175.50	37763
J_{11}	1005	25717.50	27592.50	28530	29155	31800.50	38388
J_{10}	1035	26855	28567.50	29055	29155	32125.50	38713
J_{12}	1065	27355	29317.50	29692.50	29692.50	32375.50	38963
J_1	1095	27555	29617.50	29775.83	29975.83	32525.50	39063
J_3	1125	27755	29917.50	30000.83	30100.83	32675.50	39163

Next is the gantt chart visualization with the Python program as presented in Figure 3.

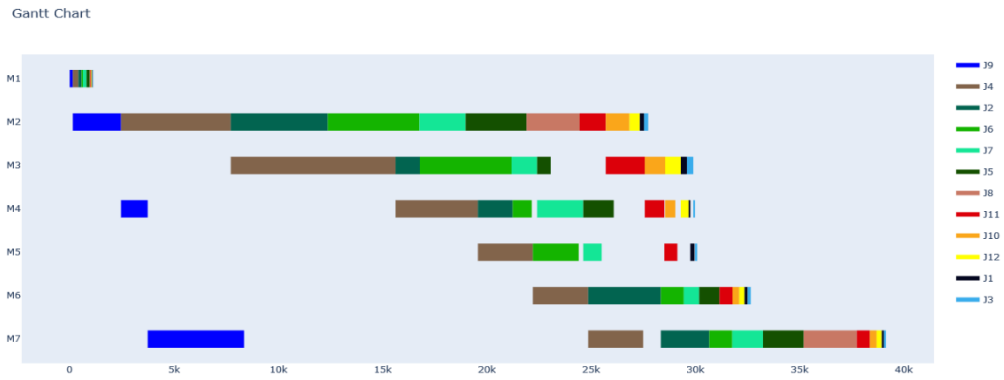


Figure 3. Gantt chart scheduling with the CDS method

3.4. Production Scheduling Using the HC

The HC method is a method based on the principle of minimizing the gaps between successive operations which will result in a higher-quality solution. To minimize the gap, it is necessary to place the job pair with the most negative gap at the end of the schedule, while the job pair with the positive gap must be placed at the beginning of the schedule because it has a better chance to compensate for the negative gap in the next jobs. The number of iteration calculations using the HC method can be determined when the iteration ends at $b = a + 2$, where b is the job at position b and a is a job at position a. In this study, there were many iteration calculations, namely 9 iterations.

The steps taken to solve the problem with the HC method are presented in (Figure 3). The following is the order of each job from the iteration results which is then calculated as the makespan value. The results obtained are presented in Table 8.

Table 8. The iteration result of the HC method

Iteration	Job Order Scheduling	Makespan (Minutes)
1	J_9-J_1-J_2-J_4-J_5-J_6-J_7-J_8-J_{10}-J_{11}-J_{12}-J_3	40735.50
2	J_9-J_1-J_{12}-J_4-J_5-J_6-J_7-J_8-J_{10}- J_{11}-J_2-J_3	38660.50
3	J_9-J_1-J_{12}-J_8-J_5-J_6-J_7-J_4-J_{10}- J_{11}-J_2-J_3	44525.50
4	J_9-J_1-J_{12}-J_4-J_8-J_6-J_7-J_5-J_{10}- J_{11}-J_2-J_3	38660.50
5	J_9-J_1-J_{12}-J_4-J_8-J_{10}-J_7-J_5-J_6-J_{11}-J_2-J_3	38660.50
6	J_9-J_1-J_{12}-J_4-J_8-J_{10}-J_{11}-J_5-J_6-J_7-J_2-J_3	38660.50
7	J_9-J_1-J_{12}-J_4-J_8-J_{10}-J_{11}-J_2-J_6-J_7-J_5-J_3	38660.50
8	J_9-J_1-J_{12}-J_4-J_8-J_{10}-J_{11}-J_7-J_6-J_2-J_5-J_3	38660.50
9	J_9-J_1-J_{12}-J_4-J_8-J_{10}-J_{11}-J_7-J_6-J_2-J_5-J_3	38660.50

Based on the table above, it can be seen that the results of the calculations using the Hc method obtained the order of the jobs with the smallest makespan, which is 38660.50, with the final work order being J_9-J_1-J_{12}-J_4-J_8-J_{10}-J_{11}-J_7-J_6-J_2-J_5-J_3. The results of the HC method makespan calculation are presented in Table 9.

Table 9. Makespan calculation method HC

	M_1	M_2	M_3	M_4	M_5	M_6	M_7
J_9	150	2460	2460	3743.33	3743.33	3743.33	8363.33
J_1	180	2660	2960	3826.66	4026.66	4176.66	8463.33
J_{12}	210	3160	3910	4285	4285	4535	8713.33
J_4	480	8430	16335	20287.50	22922.50	25575.50	28210.50
J_8	495	10980	16335	20287.50	22922.50	25575.50	30760.50
J_{10}	525	12117.50	17310	20775	22922.50	25900.50	31085.50
J_{11}	555	13367.50	19185	21712.50	23547.50	26525.50	31710.50
J_7	735	15580	20414.17	23925	24810	27263	33185.50
J_6	795	19980	24814.17	25730.84	27930.84	29030.84	34285.50
J_2	945	24630	25976.67	27139.17	27930.84	32518.34	36610.50
J_5	1095	27555	28205	29667.50	29667.50	33493.34	38560.50
J_3	1125	27755	28505	29750.83	29850.83	33643.34	38660.50

Next is the Gantt chart visualization with the Python program as presented in Figure 4.

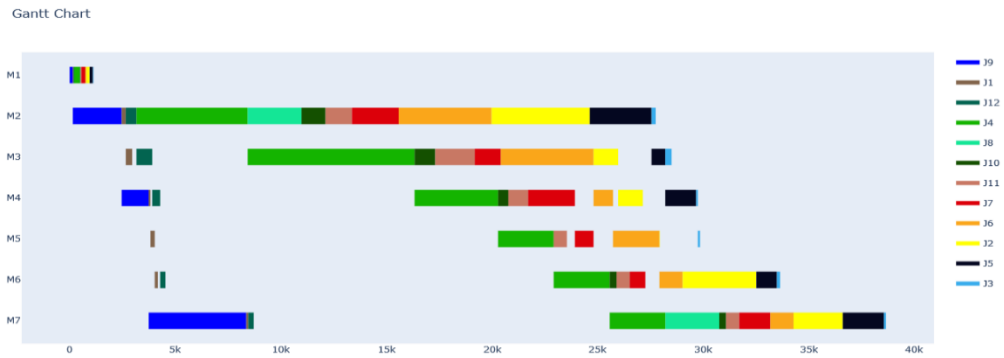


Figure 4. Gantt chart scheduling with HC method

3.5. Comparing the Performance of the Methods Used

Based on the results of calculations that have been carried out using the FCFS method, the CDS method, and the HC method, the makespan comparison results are obtained as presented in Table 10.

Table 10. Comparison of FCFS method, CDS method, and HC method

Method	Job Order Scheduling	Makespan (Minutes)
FCFS (First Come First Serve)	J_1-J_2-J_3-J_4-J_5-J_6-J_7-J_8-J_9-J_{10}-J_{11}-J_{12}	43025.50
CDS (Campbell-Dudek and Smith)	J_9-J_4-J_2-J_6-J_7-J_5-J_8-J_{11}-J_{10}-J_{12}-J_1-J_3	39163
HC (Ho and Chang)	J_9-J_1-J_{12}-J_4-J_8-J_{10}-J_{11}-J_7-J_6-J_2-J_5-J_3	38660.50

In the scheduled production process using the FCFS method or the company's initial method, the order of the schedule is J_1-J_2-J_3-J_4-J_5-J_6-J_7-J_8-J_9-J_{10}-J_{11}-J_{12} or starting from Scout Uniform → Sports Uniform → White Uniform → PDH (Daily Service Clothing) → T-shirt → Alma mater → Polo shirt → Belt → Uniform Attribute → Jacket → PLN Field Shirt → Vest This schedule takes 43025.50 minutes in the production process until all jobs are completed if in a day the working hours are 9 hours and the working day in a week is 6 working days, so this production process will be completed in approximately 80 working days.

In the scheduled production process using the CDS method, the order of the schedule is J_9-J_4-J_2-J_6-J_7-J_5-J_8-J_{11}-J_{10}-J_{12}-J_1-J_3 or starting from Belt → PDH (Daily Service Clothing) → Sports Uniform → Alma mater → Polo Shirt → Shirt → Uniform → PLN Field Shirt → Vest → Jacket → Scout Uniform → White Uniform. This schedule takes 39163 minutes in the production process until all jobs are completed, if in a day the working hours are 9 hours and the working day in a week is 6 working days, then this production process will be completed in approximately 73 working days.

In the scheduled production process using the HC method, the schedule sequence is J_9-J_1-J_{12}-J_4-J_8-J_{10}-J_{11}-J_7-J_6-J_2-J_5-J_3 or starting from Belt → Scout Uniform → Jacket → PDH (Daily Service Wear) → Uniform Attribute → Vest → PLN Field Shirt → Polo Shirt → Alma mater → Sports uniform → T-shirt → White Uniform. This schedule takes 38660.50 minutes in the production process until all jobs are completed, if in a day the working hours are 9 hours and the working day in a week is 6 working days, then this production process will be completed in approximately 72 working days.

From the makespan of the two methods, the HC method is superior to the CDS method with a difference of 502.50 minutes or about 1 working day, while when compared to the company's initial method, namely FCFS, the HC method can streamline the completion time by a difference of 4365 minutes or about 8 working days.

4. Conclusion

Based on the results and discussion above, it can be concluded that the scheduling of the Mataram Convection production process (Djagoan Kaos and Uniforms) using the HC method is superior to the CDS method with a difference of 502.50 minutes or about 1 working day, whereas when compared with the company's initial method, namely FCFS, the method HC can streamline the turnaround time by a difference of 4365 minutes or about 8 working days.

References

[1] D.H. Sulistyarini, O. Novareza, Z. Darmawan, "*Pengantar Proses Manufaktur untuk Teknik Industri*," UB Press, 2018. [GreenVersion]

[2] H.A. Taha, "*Operation Research*," *Alih Bhs. oleh Daniel Wirajaya. Bin. Aksara, Jakarta*, 1996.

[3] F. Sonata, "Sistem penjadwalan mesin produksi menggunakan algoritma Johnson dan Campbell," *J. Buana Inform.*, vol. 6, no. 3, pp. 173-182, 2015. [CrossRef]

[4] B. Bouslah, A. Gharbi, R. Pellerin, "Integrated production, sampling quality control and maintenance of deteriorating production systems with AOQL constraint," *Omega*, vol. 61, pp. 110–126, 2016. [CrossRef]

[5] A. Mail, M. Nusran, N. Chairany, T. Nur, R. Faturrahman, "Analisis penjadwalan produksi dengan e-issn 2503-1430 issn 2541-3090 menggunakan metode Campbell Dudeck Smith dan Palmer pada PT. Bobi Agung Indonesia," *J. Ind. Eng. Manag.*, vol. 3, no. 2, pp. 86-92, 2018. [CrossRef]

[6] S. Ariyanti, Adianto, R. Miharja, "Usulan penjadwalan produksi benang menggunakan metode NEH metode algoritma johnson untuk meminimasi waktu produksi di PT. Laksana Kurnia Mandiri Sejati," *J. Ilm. Tek. Ind.*, vol. 6, no. 3, pp. 157–164, 2018. [CrossRef]

[7] Hasbullah, M. Kholil, AlBayhaki, S. Riyadi, "Beef Production Scheduling Using the CDS Method and Palmer's Heuristics," *Semin. Nas. IENACO*, pp. 497–508, 2015.

[8] K. Kulsum, D.A. Utami, "Usulan perencanaan penjadwalan produksi di PT. X," *J. Ind. Serv.*, vol. 4, no. 1, 2018. [CrossRef]

[9] N. Sutiawan, "Application of genetic algorithm methods in production scheduling optimization to minimize makespan (Case study: PT Kunango Jantan)," Universitas Islam Negeri Sultan Syarif Kasim Riau, 2018.

[10] T. Anggara, A.A. Sonief, J.T. Mesin, F. Teknik, B. Malang, J.M. Haryono, "Review of the implementation of the Campbell Dudek & Smith (CDS) method on maintenance schedules and production schedules," Presented at IDEC National Seminars and Conferences 2019.

[11] Fathurohman, M. Sayuti, T.A. Lambas, "Optimasi penjadwalan produksi menggunakan metode Campbell Dudek Smith (di PT. XYZ)," *J. Ind. Xplore*, vol. 5, no. 2, pp. 69–77, 2020. [GreenVersion]

[12] R. Ginting, "*Machine Scheduling*," Graha Ilmu, 2009.

[13] M. Paendong, J.D. Prang, "Optimasi pembagian tugas karyawan menggunakan metode Hungarian," *J. Ilm. SAINS*, vol. 11, no. 1, pp. 109-115, 2011. [CrossRef]

[14] R. Kharisma, E. Ferbrianti, and L. Herlina, "Penjadwalan produksi flow shop menggunakan metode Campbell Dudek Smith (CDS) dan Nawaz Enscore Ham (NEH)," *J. Tek. Ind. Univ. Sultan Ageng Tirtayasa*, vol. 5, no. 3, p. 1432, 2017.

[15] R.L. Salam, "Penerapan algoritma Ho-Chang dan tabu search pada penjadwalan flowshop," Fakultas MIPA, Universitas Jember, 2013. [GreenVersion]

[16] J.C. Ho, Y.L. Chang, "A new heuristic for the *n*-job, *M*-machine flow-shop problem," *Eur. J. Oper. Res.*, vol. 52, no. 2, pp. 194-202, 1991. [CrossRef]